

The University of Chicago

THE EFFECT OF GRAPE AS COMPARED
WITH OTHER FRUIT JUICES ON
URINARY ACIDITY AND THE
EXCRETION OF ORGANIC
ACIDS

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
BIOLOGICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF HOME ECONOMICS AND
HOUSEHOLD ADMINISTRATION

1933

By
RUTH COWAN CLOUSE

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THE EFFECT OF GRAPE AS COMPARED WITH OTHER FRUIT JUICES ON URINARY ACIDITY AND THE EXCRETION OF ORGANIC ACIDS ¹

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SIX FIGURES

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INTRODUCTION

Effect of grape juice on urinary acidity. Numerous well-known experiments have clearly established the fact that the ingestion of large quantities of most fruits and vegetables leads, first, to an appreciable decrease in urinary acidity and, second, to an increased output of organic acids. The increased output of organic acids has usually been attributed to the elimination of a certain fraction of the fruit acids which has escaped oxidation in the tissues, although the presence of these acids in the urine has never been proved. Certain fruits, however, notably prunes, plums, and cranberries, have been observed to have an opposite effect, that is, to increase rather than decrease the total acidity of the urine (Blatherwick and Long, '23) and it has been further observed (Slattery, '25) that the ingestion of from 600 to 750 cc. of apple juice (sweet cider) may reduce, rather than increase, the organic acid content of the urine.

That grape juice may also induce a reaction different from that of other fruits is indicated by the conflicting results obtained in certain recent investigations. Pickens and Hetler

¹ Part of a dissertation submitted to the faculty of the Division of the Biological Sciences of The University of Chicago in candidacy for the degree of doctor of philosophy.

('28) have found that as much as 1 quart of grape juice daily either had no effect upon, or resulted in a slight lowering of the pH of the urine, while Saywell ('32) and Pratt and Swartout ('33 a) have observed that similar quantities of grape juice produced a marked rise in the pH of the urine of their subjects. Pickens and Hetler were, however, working with commercial Concord juice, while the other investigators have used the fresh juice of several varieties of grapes, including the Concord. The difference between his results and those of Pickens and Hetler, Saywell explains on the basis of the probable difference in alkalinity of the fruit juices used, the commercially bottled juice being considerably less alkaline than the fresh, because of the precipitation of tartrates during storage. It is also very probable that different varieties of grapes differ markedly in alkalinity of ash, since the alkalinity of fresh Concord grape juice is reported by Hartmann and Tolman ('18) to be equivalent to 48.6 cc. 0.1 N alkali per 100 cc. of juice, while Saywell reports the alkalinity of the ash of his mixture of fresh Malaga, Muscat and Petit Sirah juices to be equivalent to 74.2 cc. 0.1 N alkali per 100 gm. of juice. In this connection it should be noted that Pratt and Swartout ('33) have observed that Rochelle salts were considerably more effective in reducing the acidity of the urine than was potassium bitartrate—a result which is consistent with the difference in alkalinity of the two compounds.

Relation of organic acid excretion to acid-base balance. It has recently been suggested (Fasold, '30; Schuck, '34 a) that the excretion of organic acids in normal urine may be an important factor in the maintenance of the acid-base balance of the blood of healthy persons. Fasold has observed that the addition of sodium bicarbonate to an already alkaline (vegetable) diet greatly increases the output of organic acids, while the addition of hydrochloric acid to an acid (meat) diet greatly reduces the total organic acid excretion. He has also found ('31) that the administration of sodium or potassium salts of organic acids, such as citric or lactic acids, has the same effect upon the excretion of organic acids as has sodium bicarbonate,

while the free organic acids have the same effect as mineral acids, that is, they bring about a reduction in the total organic acids eliminated. The output of any given organic acid, for example, citric or lactic acid, when given by mouth, is sometimes increased, but may actually be reduced in the urine, especially in children. These results have recently been confirmed and extended by Schuck ('34 b) who reports that total organic acid excretion was decreased by the addition of citric acid to a constant, slightly acid basal diet, but was doubled or even tripled by the addition of chemically equivalent amounts of sodium citrate. Citric acid excretion was decreased in some cases and increased in others as the result of the citric acid ingestion, while the sodium citrate brought about a marked increase in every case. Additions of sodium bicarbonate to the basal diet also brought about small increases in the total organic acid excretion and large increases in the citric acid.

Thus, when alkalis are fed the organic acids in general, and citric acid in particular, appear to be important factors in excreting the excess. However, the output of no one acid, even citric acid (Schuck, '34 a), is sufficiently increased to account for the total increase in organic acid excretion. According to Fasold, therefore, "it is possible that there is a group of acids which . . . through the summation of their small increase in administration of alkali, effect a greatly increased output." Of the organic acids which may function as alkali excretors Fasold believes citric acid to be the most important. Others acids which may play a minor role are lactic and hippuric.

It is very probable, therefore, that the increased organic acid excretion which usually accompanies a fruit diet does not simply represent the excretion of unoxidized portions of the fruit acids, but is one of the mechanisms involved in the adjustment of the acid-base balance. As further evidence for this view, McLaughlin and Blunt's observation ('23) of an increased excretion of uric acid after a fruit meal may be cited.

EXPERIMENTAL

The following investigation was undertaken for the purpose of studying the effect of grape juice as compared with the juice of other fruits and vegetables on the acidity and total organic acid content of the urine. A second aim was to determine, if possible, the identity of the organic acids excreted on the fruit juice diets. The investigation was divided into three separate parts which will be described as experiments I, II and III.

Experiment I

Method: General procedure and diet. The first experiment was intended to be preliminary only, but the results are of sufficient interest to warrant their inclusion here. Five normal young women acted as subjects and two different fruit or vegetable juices were tested on each subject. The experiment was divided into four periods of 3 days each, as follows: period 1, basal diet; period 2, basal diet plus 1 pint of a specified fruit juice; period 3, basal diet; period 4, basal diet plus 1 pint of a second fruit juice. One preliminary day for adjustment to the fruit juice diet was usually allowed between the basal and the fruit juice periods. The basal diet was nearly neutral in reaction and the fluid intake was kept constant at about 2 liters.

The fruit and vegetable juices used were commercially bottled grape juice, both Concord and Catawba; freshly pressed juice from Thompson seedless grapes; freshly pressed orange, lemon, grapefruit, and pineapple juices; commercially bottled loganberry juice, canned sauerkraut juice; and canned tomato pulp.

Chemical analyses. The following determinations were made on 24-hour specimens of urine, collected and preserved under toluene: pH, colorimetric; titratable acidity, according to Folin ('03); and organic acids according to Van Slyke and Palmer ('20).

Results. A summary of the results of this experiment, together with the estimated alkalinity of the ash of certain of the fruit juices used, is given in table 1. All of the juices tested

were effective in decreasing the acidity of the urine, although all were not equally so. In general, the rise in the pH of the urine appeared to parallel the increase in alkalinity of the ash of the fruit juice used. Of the three varieties of grape juice tested, the fresh Thompson seedless juice was most effective in reducing urinary acidity, while the bottled Concord juice

TABLE 1

Average increase in urinary pH and total organic acid excretion of five normal women on diets containing 1 pint of a specified fruit or vegetable juice, together with the total alkalinity of the ash of some of the fruit juices used¹

FRUIT JUICE	URINE		FRUIT JUICES
	Average increase in pH	Excess organic acid	Excess alkalinity of ash per 100 gm. juice ²
		<i>per cent of intake</i>	<i>cc. N</i>
Lemon	0.4	8.1	4.55
Grape, Concord (bottled)	0.5	12.5	1.94
Grape, Catawba (bottled)	0.6	7.0	
Grapefruit	0.6	5.9	4.08
Grape, Thompson seedless (fresh)	0.7	7.3	
Loganberry	0.7	1.9	
Sauerkraut	0.7	7.5	
Orange	0.8	11.8	5.70
Pineapple	0.8	10.7	7.20
Tomato	1.0	11.4	7.19

¹ Figures for Catawba and Thompson seedless grapes, and for loganberry and sauerkraut juices are omitted in the table because average figures for these juices were not found.

² Estimated from Sherman ('27) and Sherman and Gettler ('12).

was least so. It seems highly probable that this result reflects a difference in the alkalinity of the ash of the three varieties of grapes. A further, very interesting and suggestive result of this experiment was that, with the exception of the Concord grape juice, the greatest increase in organic acid excretion occurred on the diets containing the most highly alkaline fruit juices.

Experiment II

The second experiment was planned to make a further study of the effects of grape as compared with orange and apple juices upon urinary acidity and also upon the calcium and phosphorus retention of adults.²

Orange juice was selected because of the widespread popularity of this fruit juice and because of the reports of other investigators as to its effectiveness in reducing urinary acidity (Blatherwick and Long, '22; Chaney and Blunt, '25) and in promoting calcium and phosphorus retention in children (Chaney and Blunt, '25). The apple juice was chosen because it seemed desirable to investigate further the decreased organic acid excretion found by Slattery ('25).

Method: General procedure. Since calcium and phosphorus retentions were to be determined, a complete metabolism study was carried out on each subject. A low-calcium weighed diet was taken, and both urine and feces, together with aliquot portions of the food, were collected and preserved according to the accepted technic for such studies.

Three normal women served as subjects. Since it seemed desirable to study the effects of all three juices in each of the three subjects, the experiment was divided into six periods, as follows: period 1, basal diet; period 2, basal diet plus 525 gm. bottled apple juice (commercial sweet cider); period 3, basal diet; period 4, basal diet plus 500 gm. freshly pressed orange juice; period 5, basal diet; period 6, basal diet plus 500 gm. bottled Concord grape juice. A preliminary period of 3 days on the basal diet, without collection of urine or feces, preceded period 1. The other periods were separated by one preliminary day in which the fruit juice was fed, but urine collections were not made.

Diet. Computation of the acid-base content of the various diets showed that the basal diet was moderately acid (table 2). The apple and grape juice diets were also slightly acid, but less so than the basal diet, while the orange juice diet was

² The data on calcium and phosphorus retention will be reported in a later paper.

distinctly alkaline. Using Hartmann and Hillig's ('30) figures for the tartaric and citric acid content of grapes and oranges, respectively, and the figures furnished by Slattery ('25) for the malic acid content of apple juice, the intake of these acids in the quantities of fruit juice ingested was computed to be 2.1 to 3.9 gm. malic acid in the apple juice, 4.3 gm. citric acid in the orange juice, and 3.8 gm. tartaric acid in the grape juice.

Chemical analyses. The following determinations were made on the 24-hour specimens of urine: pH, colorimetric, according to the method of Hastings, Sendroy and Robson ('25) with the use of the Hastings bicolorimeter; titratable acidity, Folin;

TABLE 2
Acid-base content of diets used in experiment II¹

DIET	PERIOD	EXCESS IN RESIDUE	
		Acid	Base
		cc. N	cc. N
Basal	1, 3, 5	19.5-23.4	
Basal, plus 525 gm. apple juice	2	5.8-10.1	
Basal, plus 500 gm. orange juice	4		4.7-8.5
Basal, plus 500 gm. grape juice	6	9.8-13.4	

¹ Estimated from Sherman ('27).

total organic acids, Van Slyke and Palmer ('20); and ammonia, Folin and Bell ('17).

Results. In this experiment apple juice proved to be strongly laxative for two of the subjects, but not at all so for the third. The other two fruit juices were mildly laxative for one subject, but not so for the others. The catharsis appears to have had little consistent effect upon the acidity of the urine, however.

The difference in the effects of the three fruit juices is clearly shown in figures 1 and 2. Figure 1 indicates that, in general, the pH of the urine was raised when approximately $\frac{1}{2}$ liter of orange juice was ingested, but remained the same when similar quantities of apple or grape juice were taken. Figure 2 shows that the total acid excretion (titratable acid

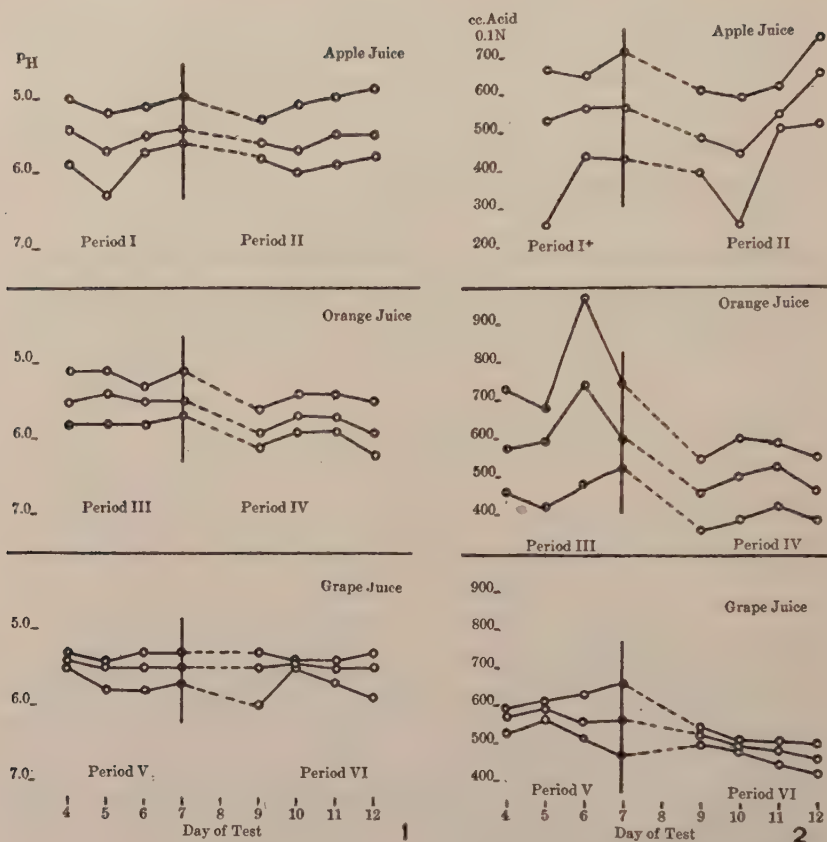


Fig. 1 Maximum, minimum and average pH of urine of three subjects on a basal diet and on the same diet supplemented with 500 gm. of a specified fruit juice (525 gm. in the case of apple juice). The heavy vertical line indicates the end of the basal diet. The dotted line indicates preliminary period on fruit juice diet.

Fig. 2 Maximum, minimum and average excretion of total acid (titratable acid plus ammonia) by three subjects on a basal diet and on the same diet supplemented with 500 gm. of a specified fruit juice (525 gm. in the case of apple juice). Heavy vertical line indicates end of basal diet. Dotted line indicates preliminary period on fruit juice diet. + Ammonia not determined on first test day.

plus ammonia) was reduced on both the grape and the orange juice diets, but that the reduction was somewhat less marked when the grape juice was fed. On the apple juice diet, on the contrary, the total acid excretion tended to increase rather than decrease. A comparison of figures 1 and 2 shows, rather surprisingly, that on the grape juice diet the reduction in total acid excretion was considerably greater than would be indicated by the very slight change in pH.

Organic acids. The excess of total organic acids excreted during the fruit juice periods, expressed in terms of per cent of intake, was greatest during period 4, when orange juice was fed. On the apple juice diet the organic acid excretion was actually reduced in two subjects, although an increase amounting to 6.4 per cent of the intake was observed in the third. In figure 3 are plotted the maximum, minimum, and average excretion of total organic acids in all six experimental periods. A comparison of figures 2 and 3 indicates that the organic acid excretion tended to be the reverse of the total acid excretion; that is, as the total acid output was reduced the organic acid output tended to rise. When there was little change in the total acid excretion, as on the apple juice diets in this experiment, the organic acid output tended to remain practically unchanged.

The CO₂-combining power of the plasma. Fitz and Van Slyke ('17) have found that the total acid excretion (titratable acid plus ammonia) bears a fairly close relationship to the CO₂-combining power of the blood, and that the latter may be computed roughly, with an error of from 3.2 to 7 volumes per cent when the following formula is used:

$$\text{Plasma CO}_2 \text{ capacity} = 80 - \sqrt{D/W \sqrt{C}}$$

where 80 is the maximum CO₂-combining power of the plasma, D the rate of excretion of 0.1 N acid plus ammonia per 24 hours, W the weight of the individual and C the cc. of 0.1 N acid plus ammonia per liter of urine. Recently, Bischoff, Sansum, Long and Dewar ('34) have reported that they could find no correlation between the plasma bicarbonate and either

the pH or the titratable acidity of the urine and, further, that any changes which did occur in the plasma bicarbonate as a result of feeding substances having either an acid or an alkaline residue were well within the range of error reported by Fitz and Van Slyke, and also within the range of variation

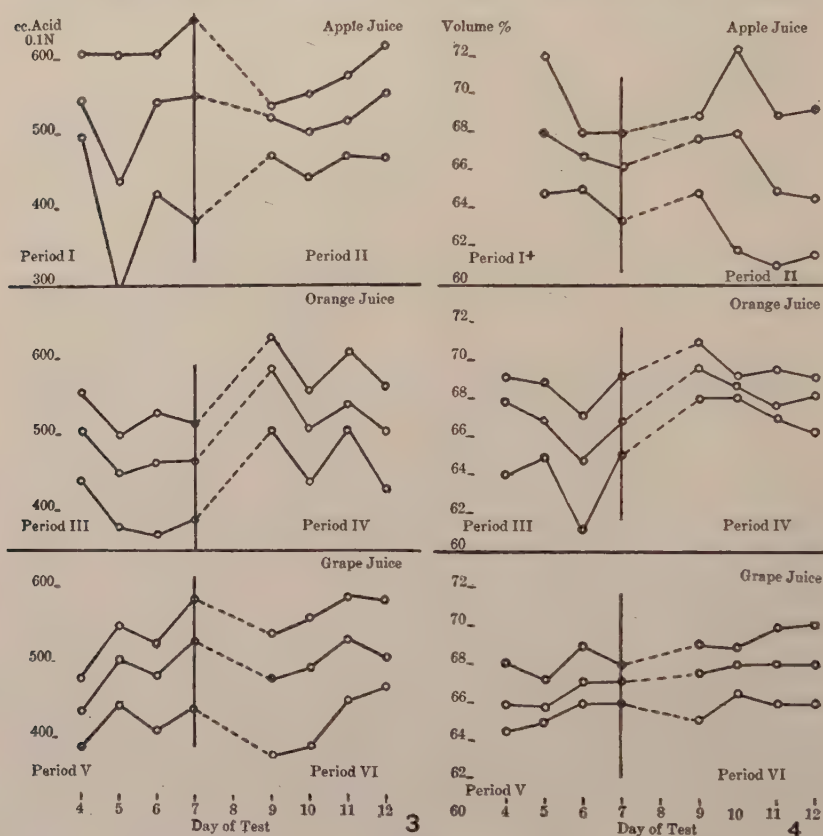


Fig. 3 Maximum, minimum and average excretion of total organic acids by three subjects on a basal diet and on the same diet supplemented with 500 gm. of a specified fruit juice (525 gm. in the case of apple juice). Heavy vertical line indicates end of basal diet. Dotted line indicates preliminary period on fruit juice diet.

Fig. 4 Maximum, minimum and average CO_2 binding power of the plasma of three subjects on a basal diet and on the same diet supplemented with 500 gm. of a specified fruit juice (525 gm. in the case of apple juice). Heavy vertical line indicates end of basal diet. Dotted line indicates preliminary period on fruit juice. + Ammonia not determined on first test day.

found in the fasting blood (taken before breakfast) of subjects on an ordinary diet. It has, nevertheless, seemed worth while to compute the values for the CO_2 -combining power of the plasma for the subjects of this experiment according to the Fitz and Van Slyke formula. The results of these computations are presented in figure 4, which shows an apparent tendency of the blood to become somewhat more acid on the apple juice diet and somewhat more alkaline on both the orange and the grape juice diets. It should be observed, however, that all of the values found in this experiment are within the normal range reported by Fitz and Van Slyke, and also, for the most part, within the range of error reported for the computation. It is therefore quite possible that no significant changes occurred in the blood, although the fact that the different juices appear to have caused different reactions seems of interest.

Experiment III

Method: General procedure. Experiment III was essentially a repetition of experiment II, except that the quantity of fruit juice taken was increased to 1000 gm. daily. Two fruit juices only, orange and grape (commercially bottled Concord), were included and but two subjects were used in the study of each fruit juice.

Diet. The basal diet used in this experiment had a potential acidity of 4.9 to 5.3 cc. of normal acid daily. Both of the fruit juice diets were potentially alkaline, the grape juice diet having a potential alkalinity of 13.0 to 14.1 cc. of normal alkali per day, while the orange juice diet contained an excess of 50.2 to 51.2 cc. of normal alkali daily. The tartaric acid intake in the grape juice diets, estimated as in experiment II, was probably in the neighborhood of 7.6 gm. daily. Since Hartmann and Hillig ('30) have recently reported that grapes also contain an average of 0.023 per cent of citric acid, the intake of citric acid on the grape juice diet probably amounted to about 0.23 gm. daily. The citric acid in the orange juice, as determined by Schuck ('34 a) amounted to 8.51 gm. daily.

Chemical analyses. pH, titratable acidity, and total organic acids were determined on the 24-hour specimens of urine as in experiment I. Ammonia determinations were not made, but instead the uric acid and citric acid output was determined daily, the former by the Folin-Shaffer method (described by Mathews, '30), and the latter by the method described by McClure ('22).³

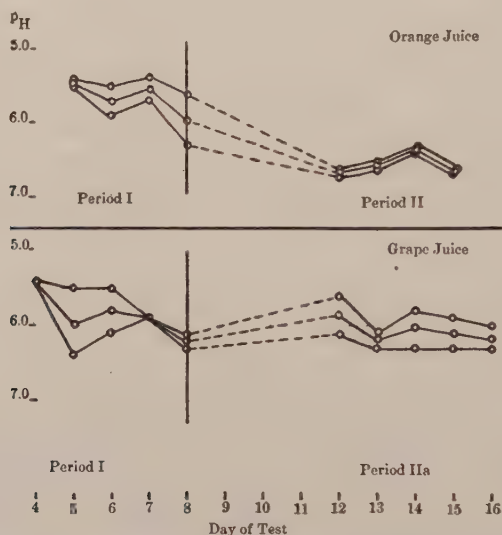


Fig. 5 Maximum, minimum and average pH of urine of two subjects on a basal diet and on the same diet supplemented with 1000 gm. of a specified fruit juice. Heavy vertical line indicates end of basal diet. Dotted line indicates preliminary period on fruit juice diet.

Results. No laxative effects of either of the fruit juices used were felt by any of the subjects in this experiment.

Urinary acidity and total organic acids. The results of experiment III are presented in figures 5 and 6. Figure 5 shows that the larger quantity of orange juice brought about a very distinct lowering of the acidity of the urine, the effect of 1000 gm. of orange juice being much more marked than that of a similar quantity of grape juice. A comparison of

³ The citric acid determinations were made by Miss Cecilia Shuck as a part of a further study of the metabolism of this acid ('34 a).

figures 1 and 5 also shows that the larger quantities of juice were decidedly more alkalinizing than the smaller quantities used in experiment II.

Figure 6 shows that in this experiment the increase in the output of total organic acids was quite similar on the two

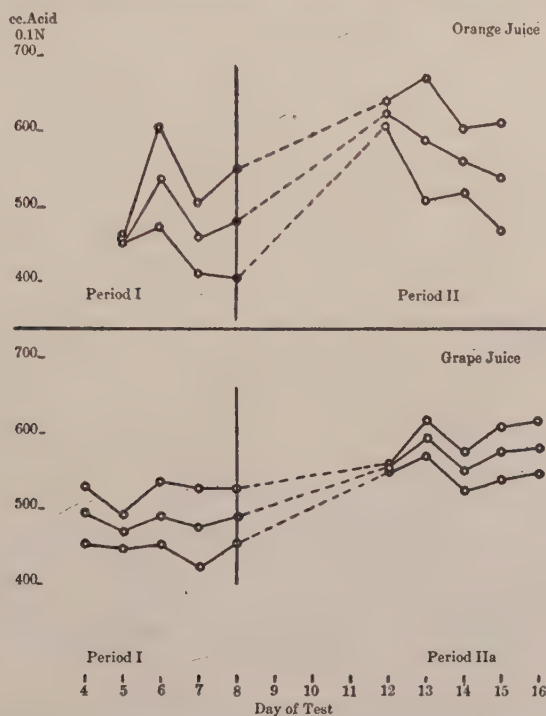


Fig. 6 Maximum, minimum and average excretion of total organic acids by two subjects on a basal diet and on the same diet supplemented with 1000 gm. of a specified fruit juice. Heavy vertical line indicates end of basal diet. Dotted line indicates preliminary period on fruit juice diet.

juices, the increase again being greater than that which occurred in experiment II (fig. 3).

Uric and citric acids. Table 3 shows that the output of both uric and citric acids was increased in all subjects on both the grape and orange juice diets. The increased uric acid output, while not large, was sufficient to account for 2.3 to 12.8 per cent of the average increase in total organic acids during the

fruit juice periods. On the orange juice diet the increase in citric acid output amounted to an average of 0.234 and 0.457 gm. per day, or 2.8 to 5.4 per cent of the intake. On the grape

TABLE 3
Average total organic, uric and citric acid output of four normal women on a basal diet and on the same diet supplemented with 100 gm. of a specified fruit juice

DIET	SUBJECT	ACID OUTPUT PER 24 HOURS		
		Total organic	Uric	Citric
Grape juice				
Basal	C	cc. 0.1 N 525	cc. 0.1 N 0.394	cc. 0.1 N 0.871
	H	447	0.363	0.634
Basal plus 1000 gm. grape juice	C	596	0.470	1.019
	H	549	0.382	0.909
Orange juice				
Basal	R	512	0.341	0.658
	K	442	0.441	0.452
Basal plus 1000 gm. orange juice	R	625	0.422	1.115
	K	537	0.479	0.686

TABLE 4
Comparison of the sum of the excess uric plus citric acids excreted on diets containing 1000 gm. of a specified fruit juice with the excess of total organic acids excreted on the same diet

FRUIT JUICE	SUBJECT	EXCESS ACID						
		Total organic	Uric	Citric	Uric plus citric		Undetermined	
		cc. 0.1N	cc. 0.1N	cc. 0.1N	cc. 0.1N	per cent	cc. 0.1N	per cent
Orange	K	94.0	4.5	36.5	41.0	44	53.0	56
Orange	R	113.0	9.6	71.4	81.0	72	32.0	28
Grape	C	70.2	9.0	23.1	32.1	36	48.1	64
Grape	H	100.4	2.3	41.7	44.0	44	56.4	56

juice diet the increase in citric acid amounted to the surprisingly high average of 0.148 and 0.275 gm. per day, an increase of 64 per cent of the intake in one subject, and more than 100 per cent in the other. Table 4 shows that the sum of the

excess uric plus citric acids in the urine during the fruit juice periods represents 44 and 72 per cent of the excess organic acid on the orange juice diet, and 36 and 44 per cent of the excess acid output on the grape juice diet. This leaves approximately one-quarter to one-half of the excess organic acid unaccounted for on the orange juice, and about one-half to two-thirds unaccounted for on the grape juice diets.

It is regrettable that determinations of tartaric acid output could not have been made in this study. However, the work of other investigators throws some light on this point. Pratt and Swartout ('33 b) were unable to find tartaric acid in the urine of their subjects after the ingestion of 1000 gm. grape juice, although they say that they "could not devise a practical procedure that would detect tartrates in a solution more dilute than one part in two thousand." Finkle ('33) has observed that 85 to 98.5 per cent of pure neutral sodium tartrate injected intramuscularly appeared in the urine within a few hours, but both Finkle and Underhill and his associates ('31) report that when from 1 to 10 gm. of either tartaric acid or its salts are taken by mouth a maximum of 20 per cent of the quantity ingested appears in the urine. No tartaric acid has been found in the feces in the investigations quoted, but the decomposition of the tartrates by human intestinal contents and by the common fecal bacteria has been observed by Pratt and Swartout ('33 b) and by Underhill and his associates ('31). It is concluded by the latter investigators that a small portion only of the tartrate taken by mouth is absorbed by man and that the human body has no power of oxidation of tartaric acid.

In view of the above facts, it is possible, though it hardly seems probable, that the entire amount of undetermined excess acid in the urine on the grape juice diet was tartaric. If such had been the case, the total excretion of tartaric acid would have amounted to something less than 5 per cent of the intake. In any event, it is not possible to explain the failure of grape juice to lower the pH of the urine as efficiently as does orange juice on the basis of the excretion of large quantities of tartaric acid.

SUMMARY

The effect of various fruit and vegetable juices, especially of bottled apple juice, fresh orange juice, and bottled Concord grape juice, upon the urinary acidity and total organic acid output of normal adult women has been compared, with the following results:

1. The ingestion of orange juice has produced a more marked effect upon the alkalinity of the urine (as measured by an increase in pH and a reduction in titratable acidity and ammonia) than has the ingestion of either grape or apple juice.

2. The effect of bottled Concord grape juice has been variable, although usually in the direction of an alkalization of the urine.

3. The effect of apple juice has also been variable, with a tendency toward an increased acidity of the urine.

4. Both grape and orange juices tend to produce an increase in the CO_2 -combining power of the blood, as calculated by the Fitz and Van Slyke formula. Apple juice, on the contrary, tends to produce a decrease in CO_2 -combining power.

5. The ingestion of both grape and orange juices produces an increased excretion of organic acids. The ingestion of apple juice, however, is often accompanied by a decreased organic acid output.

6. The increase in organic acid output observed on both the orange and grape juice diets is in part due to an increased excretion of uric plus citric acids. The increase in organic acid output is not entirely due, therefore, to the excretion of unoxidized remnants of individual fruit acids.

7. The data on organic acid excretion obtained in this investigation are believed to support the suggestion that the organic acids play a significant role in the maintenance of acid-base balance in the body.

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